Metropolitan Transportation Commission

bart
impact
program

LAND USE AND URBAN DEVELOPMENT PROJECT

ACCESSIBILITY MAPPING

working paper

The BART Impact Program is a comprehensive, policy-oriented study and evaluation of the impacts of the San Francisco Bay Area's new rapid transit system (BART).

The program is being conducted by the Metropolitan Transportation Commission, a nine-county regional agency established by state law in 1970.

The program is financed by the U. S. Department of Transportation, the U. S. Department of Housing and Urban Development, and the California Department of Transportation. Management of the Federally funded portion of the program is vested in the U. S. Department of Transportation.

The BART Impact Program covers the entire range of potential rapid transit impacts, including impacts on traffic flow, travel behavior, land use and urban development, the environment, the regional economy, social institutions and life styles, and public policy. The incidence of these impacts on population groups, local areas, and economic sectors will be measured and analyzed. Finally, the findings will be interpreted with regard to their implications for the planning of transportation and urban development in the Bay Area and other metropolitan areas.

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BART IMPACT PROGRAM

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ACCESSIBILITY MAPPING

September 1977

WORKING PAPER

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PREPARED FOR

U.S. DEPARTMENT OF TRANSPORTATION

AND

U.S. DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT

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16. Abstract

This working paper addresses BART's effects on accessibility at a regional scale and within station areas. Several accessibility measures are presented, and differences between BART and the No-BART Alternative (NBA) are delineated. Auto access times to selected BART stations are mapped and compared with the frequency distribution of travel times to BART reported in the MTC Passenger Profile Survey of 1976. The maps and accessibility measures will be used in analyzing BART's effects on office construction and the housing industry, workplace and residence location decisions, retail sales trends, property values and rents, and other facets of urban development.

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SAN FRANCISCO BAY REGION

CENTRAL AREA

Metropolitan Transportation Commission

BART: The Bay Area Rapid Transit System

Length: The 71-mile system includes 20 miles of subway, 24 miles on elevated structures and 27 miles at ground level. The subway sections are in San Francisco, Berkeley, downtown Oakland, the Berkeley Hills Tunnel and the Transbay Tube.

Stations: The 34 stations include 13 elevated, 14 subway and 7 at ground level. They are spaced at an average distance of 2.1 miles: stations in the downtowns are less than one-half mile apart while those in suburban areas are two to four miles apart. Parking lots at 23 stations have a total of 20,200 spaces. There is a fee (25 cents) at only one of the parking lots. BART and local agencies provide bus service to all stations.

Trains: Trains are from 3 to 10 cars long. Each car is 70 feet long and has 72 seats. Top speed in normal operations is 70 mph with an average speed of 36 mph including station stops. All trains stop at all stations on the route.

Automation: Trains are automatically controlled by the central computer at BART headquarters. A train operator on board each train can override automatic controls in an emergency.

Magnetically encoded tickets with values up to $20 are issued by vending machines. Automated fare gates at each station compute the appropriate fare and deduct it from the ticket value. At least one agent is present at each station to assist patrons.

Fares: Fares range from 25 cents to $1.45, depending upon trip length. Discount fares are available to the physically handicapped, children 12 and under, and persons 65 and over.

Service: BART serves the counties of Alameda, Contra Costa and San Francisco, which have a combined population of 2.4 million. The system was opened in five stages, from September, 1972, to September, 1974. The last section to open was the Transbay Tube linking Oakland and the East Bay with San Francisco and the West Bay.

Routes are identified by the terminal stations: Daly City in the West Bay, Richmond, Concord and Fremont in the East Bay. Trains operate from 6:00 a.m. to midnight on weekdays, every 12 minutes during the daytime on three routes: Concord-Daly City, Fremont-Daly City, Richmond-Fremont. This results in 6-minute train frequencies in San Francisco, downtown Oakland and the Fremont line where routes converge. In the evening, trains are dispatched every 20 minutes on only the Richmond-Fremont and Concord-Daly City routes. Service is provided on Saturdays from 9 a.m. to midnight at 15-minute intervals. Future service will include a Richmond-Daly City route and Sunday service. Trains will operate every six minutes on all routes during the peak periods of travel.

Patronage: Approximately 142,000 one-way trips are made each day. Approximately 200,000 daily one-way trips are anticipated under full service conditions.

Cost: BART construction and equipment cost $1.6 billion, financed primarily from local funds: $942 million from bonds being repaid by the property and sales taxes in three counties, $176 million from toll revenues of transbay bridges, $315 million from federal grants and $186 million from interest earnings and other sources.

March 1978

PREFACE

The BART Impact Program (BIP) is a comprehensive policy-oriented effort to identify, describe, measure, and present findings as accurately as possible about the multi-faceted impacts of a major public transportation investment -- the BART system. The major objective of the Land Use and Urban Development Project is to determine how and to what extent BART has influenced the spatial arrangements of people and activities within the San Francisco Bay Area. To accomplish this task, the project will focus on the way BART has influenced (1) location decision processes; (2) actual movement behavior that results from those decisions and other market forces; and (3) the form, character, and functioning of aggregate spatial groupings that represent the net outcome of those decisions and movement patterns. Changes attributable to BART will be measured against pre-BART and no-BART alternatives. In all of these studies, BART's effects on individual socio-economic groups, particularly minorities and the disadvantaged, will receive careful attention.

The Land Use and Urban Development Project is one of six major projects comprising the BART Impact Program. The others are:

- Economics and Finance Project (E&F)
- Environment Project (Env)
- Institutions and Lifestyles Project (ILS)
- Public Policy Project (PP)
- Transportation System and Travel Behavior Project (TSTB)

Each of these projects is designed to investigate specific aspects of BART's impacts, to explain why the impacts occur, and to identify who is affected by the impacts and the distributional effects. The projects then will demonstrate how the information derived can be used by decision-makers to enhance the benefits and to reduce the disbenefits of BART, and to increase understanding of the potential impacts of rail rapid transit investments in the Bay Area and other American metropolitan areas.

This Working Paper presents the analysis and findings of the study of BART's impact on accessibility -- one aspect of BART's impacts on land use and urban development. The paper is presented for review by BART Impact Program staff, federal sponsors, and other interested planners and researchers. Comments on this paper as well as further analysis of BART's impacts will be incorporated in the final report.

SUMMARY

OBJECTIVES

One of the first tasks of the Land Use and Urban Development Project was to quantify, analyze, and map the relative improvement in accessibility provided by BART. Measures of accessibility -- theoretical travel time comparisons -- and mobility -- trip time comparisons -- were formulated in coordination with the Transportation System and Travel Behavior (TSTB) Project so that points of comparison would be used in both projects. Specific questions addressed in the Accessibility Mapping work element include:

- How did BART affect regional accessibility to employment centers and shopping centers?
- What are the differences in accessibility and mobility gains between peak and off-peak time periods?
- What are the differences in accessibility and mobility from older urban areas and outlying suburban areas to downtown employment centers and shopping centers? Where are the areas with the greatest accessibility and mobility gains?
- Within catchment areas, what are the relative differences in driving times to selected BART stations?

The principal objective of this work element was to develop an information base for the analysis of BART's effects on the office construction and housing industries, workplace and residential location decisions, retail sales trends, and development patterns within the BART corridors.

METHODOLOGY

BART's accessibility impacts were gauged using the 440 zone system and the No-BART Alternative (NBA) defined by MTC as the point of comparison. Differences in transit travel time on the BART and NBA networks to selected origins and destinations were computed for peak and off-peak time periods with a variety of weighting techniques to show both potential and actual gains.

Station area auto access maps were prepared using a computer travel time mapping procedure and adjusting the results to reflect local conditions. These show peak period driving times to selected BART stations in three minute intervals.

FINDINGS

The principal findings of the analysis of BART's effects on accessibility and mobility can be summarized as follows:

- BART offers a measurable improvement in area-wide accessibility to about 34 percent of the four-county service area population with a median improvement in average peak hour transit travel time of 14 minutes over the NBA.

- BART's effect on mobility, taking actual trips into account, is less marked with the average work trip on transit to major employment centers shortened by 8.7 minutes (20 percent), and the average shopping trip by 2.8 minutes (8 percent).

- Geographically the greatest accessibility and mobility gains are found along the Fremont BART line, followed in descending order by the Concord line, the Daly City line, and the Richmond line.

- BART ridership rates, patrons per thousand population, are not uniformly correlated with accessibility and mobility gains because destinations of residents and attributes of competing modes still may make BART less attractive. Communities with BART ridership per thousand residents above median (40.0) include Daly Cty (50.8), El Cerrito (56.6), Hayward (43.2), Pleasant Hill (40.5), and Walnut Creek (70.5), while the lowest ridership rates are found in Fremont (22.1) and Richmond (18.3).

- In all but end-of-the-line communities directly served by BART, 75-90 percent of the patrons live within 10 minutes driving time of the station.

Because further study of BART's mobility impacts are being conducted by the TSTB Project, these findings should not be viewed as conclusive. However, the measures presented in this working paper do provide the basis for an assessment of BART's impacts on urban development.

The limitations of using a regional transportation modeling system not specifically designed for analyzing BART's accessibility impacts should be clearly recognized. Thus, assumptions about travel times from the zone centroid to a BART station, average waiting times, transfer times and run times, as well as estimates of zone to zone trips may only be accurate within a range of 10 to 20 percent. Because the gains attributable to BART are small and quite sensitive to changes in these assumptions, the "savings" should be interpreted with a potential error factor of at least 10 percent in mind.

1. INTRODUCTION

The purpose of the Accessibility Mapping Work Element of the Land Use and Urban Development (LU&UD) Project was to determine, quantify, and summarize in graphic and tabular form the BART and No-BART Alternative (NBA) accessibility measures that will be used in analyzing BART's effects on office construction and the housing market, workplace location decisions, retail sales trends, property values and rents, and other facets of urban development. The analysis and mapping described in this Working Paper builds on, but does not duplicate, studies of BART's impacts on accessibility conducted by the Transportation System and Travel Behavior (TSTB) Project.

Pre-BART (1971) and BART (1976) comparisons were reported in the July, 1975 TSTB Project Working Paper entitled Exploratory Network Analyses of BART's Impacts on Accessibility, while BART versus the NBA comparisons were presented in a December, 1976 Working Note, Analysis of BART's Accessibility Impacts. In each case the analysis addressed differences in accessibility without reference to actual travel patterns. When travel time differences are weighted by actual trips, the BART Impact Program defines this as mobility analysis. This paper includes an assessment of both accessibility impacts and mobility impacts as they pertain to the specific study areas and research hypotheses to be addressed in the Land Use and Urban Development Project. Further, BART-NBA accessibility comparisons presented in this paper have greater validity than earlier comparisons because minor errors in the computer-coded transportation network have been corrected. Changes incorporated in the networks used for accessibility mapping include adding the Embarcadero BART station and feeder bus routes to BART, changing AC Transit transbay travel headways to correspond with actual schedules, and other minor revisions in transit links and travel times.

2. METHODOLOGY

OBJECTIVES

The primary objectives of the Accessibility Mapping Work Element were (1) to define as precisely as possible the BART and No-BART Alternative (NBA) accessibility measures to be quantified and mapped that will be of greatest use to the LU&UD Project; (2) to identify points of coordination with the TSTB Project; (3) to recommend an accessibility analysis and mapping procedure; and (4) to summarize and interpret BART's impacts on accessibility as they relate to the LU&UD Project. The TSTB Project was responsible for conducting the analysis of area-wide changes in accessibility and mobility attributable to BART.

More specifically, the accessibility mapping effort was structured to answer the following questions:

- How did BART affect regional accessibility to employment centers and shopping centers?
- What are the differences in accessibility and mobility gains between peak and off-peak time periods?
- What are the differences in accessibility and mobility from old urban areas and outlying suburban areas to downtown employment centers and shopping centers? Where are the areas with greatest accessibility and mobility gains?
- Within catchment areas, what are the relative differences in driving time to selected BART stations?

Using the MTC Travel Demand Forecasting System, (MTCFCST) BART's relative share of total travel by purpose and time period could have been estimates of transit travel in the NBA. The main components of the NBA are defined by MTC as the transportation system most likely to have evolved had the decision to build BART not been made in 1962.[1] For the most part the NBA consists of the 1971 regional transit system with minor improvements in bus service — a comparable level of investment in transit is not assumed. However, inconsistencies between the 1976 BART and NBA networks and the NBA rationale as well as problems encountered in validating the regional travel model system limited the level of analysis that could be conducted within the time constraints imposed by the LU&UD Project schedule. These issues will be addressed by the TSTB Project as the technical problems are resolved.

1. Metropolitan Transportation Commission, Rationale and Specification for the No-BART Alternative (Berkeley, California, BART Impact Program Working Note, September 1976).

APPROACH

In the BART Impact Program the concept of accessibility is defined as the potential impedance to travel between any two locations -- origins and destinations -- measured in terms of travel time and/or travel cost. When viewed in this fashion, actual travel behavior is ignored, and measures of accessibility changes -- impacts attributable to BART -- treat travel between all origins and destinations equally, whether or not people actually make such trips. If accessibility analyses are weighted to reflect travel patterns, this is defined as mobility analysis in the BART Impact Program. In both instances, an impact is expressed as the difference in travel time or cost -- either weighted or unweighted -- between theoretical travel on a BART transportation network versus travel on an NBA network. A weighted comparison simply reflects the distribution of people by workplace and residence location in the San Francisco Bay Area, while an unweighted comparison treats all potential trips equally.

In the TSTB Project, four types of accessibility and mobility measures were examined: "One to one," "many to one," "one to many," and "many to many." Each of these involves a different computation of zone to zone differences in travel time and cost, using as an information base the MTC 440 Zone System and the computer-coded highway and transit network. For the LU&UD Project, the following measures were judged most useful for an assessment of BART's land use impacts:

- Many to many analysis: Changes in area-wide accessibility based on an unweighted comparison of BART and NBA travel times between zones with transit service common to both networks.

- Many to one analysis: Changes in accessibility and mobility to selected employment centers from all other zones.

- Many to one analysis: Changes in accessibility and mobility to selected shopping centers from all other zones.

- One to many analysis: Changes in households' accessibility and mobility from selected communities to all major work places.

The one to many change in accessibility attributable to BART is defined as the actual or percentage difference in an average travel time in minutes (A) from each zone (i) to all other zones (j = 1. . .n) common to both networks. Mathematically, this is expressed as:

(1)
$$A_i = \frac{\sum_{j=1}^{n} (I_{ij})}{(n-1)}$$

Where I_{ij} = Transit travel in minutes between origin zone (i) and destination zone (j) on the 1976 BART or NBA network.

Many to one measures are computed in the same way, except that travel time to a destination zone, rather than from an origin zone, is used.

A mobility measure (M) is similar to the accessibility measure, with the estimated number of zone to zone trips used for weighting purposes. Thus:

(2)
$$M_i = \frac{\Sigma^n_{j=1} (I_{ij} \times T^k_{ij})}{\Sigma^n_{j=1} (T^k_{ij})}$$

Where T^k_{ij} = Estimated trips between i and j of type k.

When comparing mobility to employment centers, home-based work trips would be used for weighting, while for the shopping center mobility analysis, the weighting factor is the estimated number of home-based nonwork trips.

The many to one measures express differences in accessibility and mobility to specific employment centers, such as downtown San Francisco and downtown Oakland, or shopping areas served by BART, such as San Francisco's Union Square or El Cerrito Plaza. The many to one analysis focuses on changes in service to a specific destination. By contrast, one to many measures are intended to show differences in average travel time (from a selected residential community served by BART) to all major employment zones within the BART service area. Many to one measures will be used in analyzing BART's impacts on workers' and employers' location decisions and the office construction industry, while one to many measures will be incorporated into the study of households' location decisions and BART's effects on the housing industry, particularly in outlying areas.

To test the hypothesis that BART's effects decrease with distance from a station, or conversely that more benefits accrue to those living closer to BART, a series of station area access maps were prepared. These show access times, in three minute intervals, for peak period automobile travel to and from the station -- principal access mode for most BART riders using non-downtown stations.

For analysis purposes, the study area was defined as the 229 zone BART service area, which includes Alameda, Contra Costa, and San Francisco counties and Daly City-Pacifica in northern San Mateo County (zone #73-216, 346-349, 359-365, and 367-440).

No specific analyses were conducted for the LU&UD Project showing how minorities might have been affected differently because the TSTB Project had already analyzed comparative travel times -- BART versus the NBA -- for minorities and other socio-economic groups as one means of showing how BART potentially could improve accessibility for work, shopping, and social/recreational trips.[2] Since the same data base would have been employed by the LU&UD Project, little could be done to improve upon their findings. Even though trips

2. Jefferson Associates, Inc., Impacts of BART on Travel of Ethnic Minorities (Berkeley, California, BART Impact Program Technical Memorandum, Oct., 1977).

taken by minority group members can not be identified separately from those taken by the population at large, locations selected for accessibility and mobility analysis include zones with predominant minority populations. Thus the analyses do provide some indication of BART's relative impact on the mobility of minorities. Correlation of these measures with the surveys of workers, residents, and shoppers to be conducted under Work Elements 3, 4, and 9 should provide a good base for determining how BART might have affected the mobility of minorities differently. Finally, with completion of MTC's Minority Transportation Needs Assessment Project (MTNAP), up-to-date map information on the distribution of minorities throughout the Bay Area is available.[3] These maps will be used in conjunction with the station area access maps and the regional mobility comparisons in Work Element 7 to determine the extent to which minorities have been helped or hurt more than other socio-economic groups living in the BART service area.

Travel time-cost comparisons were not analyzed and mapped because they had been addressed in the TSTB Project December 1976 working note. Overall BART travel time-cost averages were reported to be 16 percent lower than those calculated for the NBA. For 48 percent of the zone-to-zone connections common to both networks BART offers a savings in travel time-costs of $1.00 or more, while for the balance of the "paths" the difference is either less than $1.00, or the NBA has a lower travel time-cost. Only in 9 percent of the network paths analyzed does the NBA offer a travel time-cost advantage of $1.00 or more. These earlier findings confirm that BART reduces both travel times and costs when compared with the NBA, thus justifying the LU&UD Project's focus on travel times as the principal measure of trip benefits.

Some analysts have proposed that accessibility measures should reflect benefits at the trip end, such as increased employment or shopping opportunities, as well as the travel time and cost differences associated with a transportation improvement.[4] However, because the MTC Travel Demand Forecasting System was not used to quantify zonal differences in trip-making and travel behavior on the two networks, such accessibility measures could not be formulated and mapped. The substitute destination question — does BART affect travel choices — also was not addressed in the accessibility mapping effort because such detailed comparisons were not made.

Capacity constraints on freeways and bridges are reflected in the peak hour travel time calculations for the highway network, but these factors were not explicitly addressed in the accessibility and mobility comparisons which focused mainly on comparisons between the two transit networks, assuming no change in the regional highway system. Similarly, constraints on access to the BART system related to the capacity of the parking lots and the feeder bus system were not included in the area-wide accessibility and mobility comparisons because they have no bearing on travel time comparisons. Further, this subject was studied by the TSTB Project.[5]

3. Jefferson Associates, Inc., Minority Transportation Needs Assessment Project Phase I Report (Berkeley, California, Metropolitan Transportation Commission, November, 1977).
4. H. Neuberger, "User Benefits in the Evaluation of Transport and Land Use Plans" (Journal of Transport Economic Policy:5 (1971), 57-75).
5. Peat, Marwick, Mitchell & Company, BART Station Access Case Studies (Berkeley, California: BART Impact Program Working Note, April, 1977).

LIMITATIONS

The transportation network and travel time on which the accessibility mapping and mobility analyses are based was designed for regional transportation planning in the nine county Bay Area, and was not specifically created for the BART Impact Program. Thus, the comparisons presented in this paper must be viewed with the inherent limitations of the regional modeling system in mind. Within station areas, for example, the contour lines depicted on the maps should be considered illustrative of relative differences in accessibility to BART, and not reflecting precisely the actual travel time from any specific location to a BART station. However, they are appropriate for identifying and isolating impacts attributable to BART.

EFFECTS ON ACCESSIBILITY

Only in isolated instances has BART had a dramatic impact on area-wide accessibility, with less than 5 percent of the traffic zones in the BART service area exhibiting gains in average travel time over 25 percent, in comparison with the NBA. The median improvement in accessibility is about 14 minutes. In fact, due to the specification of the NBA, about 9 percent of the zones within the BART service area showed a decrease in areawide accessibility, primarily because areas formerly served by Greyhound now are served by BART feeder buses and the transfer time penalty increases the total travel time. Areas with the greatest accessibility gains are shown on the map on the following page.

Within the BART service area in 1975, about 510,000 people, 21 percent of the population, lived within zones from which BART offers over a 15 percent improvement in areawide accessibility, and another 345,000, or 14 percent, lived in areas where BART offers an 11-15 percent improvement. From the standpoint of the workplace, BART offers about 216,000 jobholders, 19 percent of those working within its service area in 1975, an over 15 percent improvement in areawide accessibility, and an additional 256,000 or 22 percent potentially benefit from an 11-15 percent improvement in areawide accessibility. Proportionally, the greatest gains accrue to those living or working in Alameda County and northern San Mateo County. County by county comparisons showing the actual percent of population living or working within zones for which BART provides improved accessibility when compared with the NBA are shown in Table 1.

Decreases in accessibility with the BART network potentially affect 76,600 people in Contra Costa County (13.7 percent) of the population), 27,100 in Alameda County (2.6 percent of the population), and 21,850 in northern San Mateo County (12 percent of the population). Average travel time from zones in which these people live to all other zones common to both networks increases 14 minutes with BART.

To place these county-wide summaries in perspective, Table 2 shows average travel times for BART and NBA to zones common to both networks for selected employment centers, shopping centers, and residential areas. For example, BART reduces the average transit travel time into the San Francisco central business district from all zones from 73 minutes in the NBA to 63 minutes, a difference of 14 percent. Similar gains are shown for the Oakland central business district and the Mission District of San Francisco. The Richmond central business district is less well served by BART primarily because of the transfer required at MacArthur station, which increases the total travel time to areas without through service from Richmond. Fremont, Union City, and Hayward show greater gains in accessibility because of the clearly superior service BART offers longer distance travelers.

The reader interested in zone to zone comparisons of BART and NBA travel times and travel costs for trips to/from San Francisco, Oakland, Fremont, Richmond, and Walnut Creek should consult the TSTB Project December 1976 Working Note.

TABLE 1. DISTRIBUTION OF BART'S ACCESSIBILITY IMPACTS BY COUNTY

(1975 Population and Employment Served)

	Improvement in Areawide Accessibility: BART v. NBA					
	Over 15 Percent		10.1-15 Percent		Total	
	Population	Employment	Population	Employment	Population	Employment
Alameda County						
Number Served	323,470	115,650	158,150	73,802	1,057,820	434,270
Percent of Total	30.6	26.6	15.0	17.0		
Contra Costa County						
Number Served	26,860	29,410	34,260	8,330	560,690	160,060
Percent of Total	4.8	18.4	6.1	5.2		
San Francisco County						
Number Served	88,590	60,760	133,460	170,540	647,950	495,410
Percent of Total	13.7	12.3	20.6	34.4		
North San Mateo County						
Number Served	68,860	10,170	19,490	3,410	189,900	54,150
Percent of Total	36.3	18.8	10.3	6.3		
Total						
Number Served	507,780	215,990	345,360	256,080	2,456,360	1,143,890
Percent of Total	20.7	18.9	14.1	22.4		

Source: Metropolitan Transportation Commission; Association of Bay Area Governments, Series III Population and Employment Estimates, March 1977.

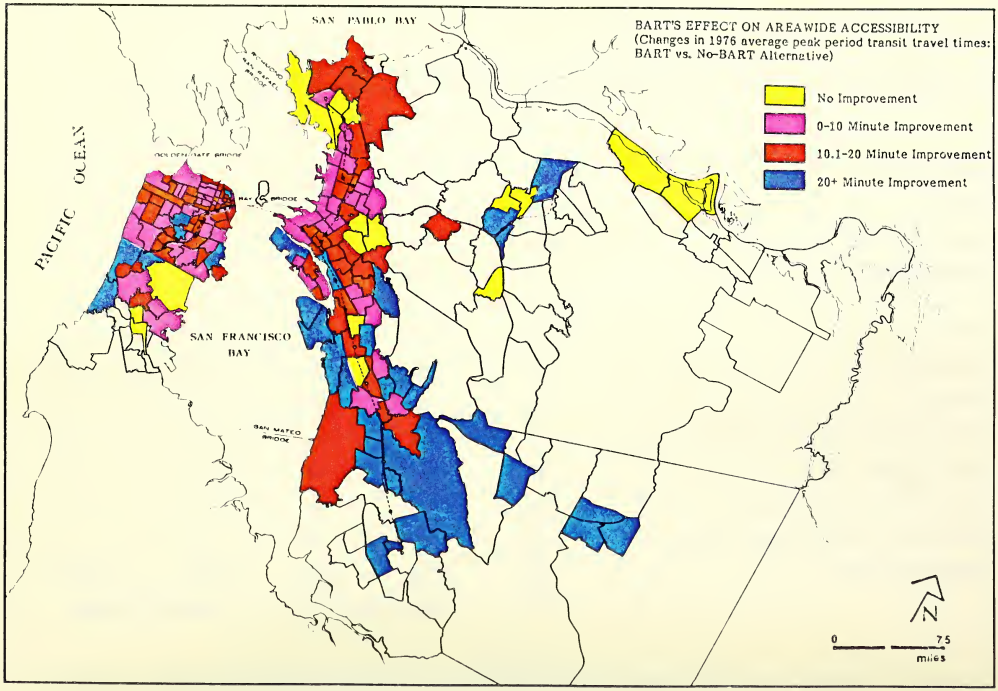

BART'S EFFECT ON AREAWIDE ACCESSIBILITY
(Changes in 1976 average peak period transit travel times:
BART vs. No-BART Alternative)
No Improvement
0-10 Minute Improvement
10.1-20 Minute Improvement
20+ Minute Improvement
SAN PABLO BAY
PACIFIC OCEAN
GOLDEN GATE BRIDGE
BAY BRIDGE
SAN FRANCISCO BAY
SAN MATEO BRIDGE
N
0
7.5
miles

TABLE 2. AVERAGE 1976 PEAK HOUR TRANSIT TRAVEL TIME COMPARISONS FOR SELECTED LOCATIONS
(Minutes)

Employment Centers	MTC Zone	Average Travel Time[a]		Savings with BART	
		BART	NBA	Actual	Percent
San Francisco Central Business District	422	63	73	10	14
Oakland Central Business District	144	70	83	13	16
Mission District	387	73	84	11	14
Richmond Central Business District	118	109	118	9	7.6
Berkeley	130	96	89	7	7.3
East Oakland	161	87	108	21	19
Fremont	203	138	220	82	37
Residential Areas					
Walnut Creek	98	110	132	22	17
Pacifica	347	123	162	39	24
South Hayward	192	105	208	103	50

a. Computed as the average peak hour transit travel time to all zones common to both networks using travel times plus time spent waiting for a BART train or bus or transferring weighted by a factor of 2.5.

Source: Metropolitan Transportation Commission

EFFECTS ON MOBILITY

When trips actually made are taken into account, the difference between BART and the NBA is less pronounced. For example, work trips to major employment centers — San Francisco, Oakland, and Richmond central business districts; Mission District, East Oakland, Berkeley, and Fremont — average 8.7 minutes less on the BART network than on the NBA, 35.7 vs. 44.4 minutes, representing a saving of 20 percent. Trip time reductions range from 1.3 minutes to Richmond to 13.5 minutes to East Oakland and 24.8 minutes to Fremont. By contrast, the accessibility analysis — many-to-one comparisons which ignored actual travel patterns — showed an average travel time savings to these seven employment centers of 21.9 minutes with BART, a decrease of 30 percent from the NBA average. Individual transit trip time comparisons to selected employment centers are summarized in Table 3.

During off-peak hours BART's relative advantage decreases because the level of service offered is closer to that assumed in the NBA network. Average midday trip times to downtown San Francisco and Oakland are reduced 2.8 minutes and 4.5 minutes respectively, differences of 9.4 and 12.5 percent. Trip time reductions to the Fruitvale and Bay Fair shopping centers are 3.7 minutes and 5.1 minutes lower on the BART network, but average off-peak transit travel times to the Mission District and El Cerrito Plaza are virtually identical on the BART and NBA networks. The individual trip time comparisons for these shopping areas also are given in Table 3.

This relatively modest impact on off-peak travel times would suggest shoppers' gains in mobility attributable to BART are likely to be small — a finding substantiated in part by the 1976 Passenger Profile Survey which showed that only 11 percent of the trips taken on BART are for personal business, shopping, doctors' appointments, banking, etc. Work trips, on the other hand, account for close to 60 percent of BART's patronage.

Looking at BART's effects on mobility from the perspective of those living in outlying communities, the one-to-many analysis revealed savings in average work trip times ranging from 8.1 minutes (14 percent) in Walnut Creek to 6.7 minutes (7.3 percent) in Fremont, and 6.1 minutes (13 percent) in El Cerrito. Average work trip and shopping trip travel time comparisons for other residential communities in the West Bay and the Mission District are summarized in Table 4.

The transit trip time comparisons in themselves only show where the greatest gains in mobility are, given the specifications of the NBA; they do not indicate where BART riders actually live. To complement this analysis and provide a basis for analyzing and interpreting households' location decisions, housing construction and development trends in the BART corridors and BART ridership by community were estimated using the 1976 BART Passenger Profile Survey (see Table 5).

Communities with average BART ridership per thousand residents above the median (40.0) include Daly City (50.8), El Cerrito (56.6), Hayward (43.2), Pleasant Hill (40.5), and Walnut Creek (70.5), while the lowest ridership rates are found in Fremont (22.1) and Richmond (18.3).

TABLE 3. AVERAGE TRANSIT TRIP TIME COMPARISONS TO SELECTED DESTINATIONS
(Peak Period Work Trips and Off-Peak Shopping Trips in Minutes)

Employment Centers	MTC Zone	Weighted Average[a] Trip Time BART	NBA	Savings with BART Actual	Percent
San Francisco CBD	422	30.1	33.9	3.8	11
Oakland CBD	144	33.4	41.0	7.6	18
Mission District	387	29.0	32.4	3.4	10
Richmond CBD	118	37.9	39.2	1.3	3.3
Berkeley	130	33.0	39.3	6.3	16
East Oakland	161	34.9	48.4	13.5	28
Fremont	203	51.4	76.2	24.8	32
AVERAGE		35.7	44.4	8.7	20
Shopping Areas					
San Francisco CBD	422	27.0	29.8	2.8	9.4
Oakland CBD	144	31.5	36.0	4.5	12.5
Mission District	387	24.0	24.0	-	-
Fruitvale	159	34.1	37.8	3.7	9.8
El Cerrito Plaza	121	34.5	35.0	0.5	1.5
Bay Fair	179	39.2	44.3	5.1	11.5
AVERAGE		31.7	34.5	2.8	8.0

(a) Computed as a many-to-one measure using estimated zone to zone work trips and shopping trips for weighting purposes.

Source: Metropolitan Transportation Commission; Peat, Marwick, Mitchell & Co., Inc.

TABLE 4. AVERAGE TRANSIT TRIP TIME COMPARISONS FROM SELECTED ORIGINS
(Minutes)

Residential Area	MTC Zone	Weighted Average Trip Times[a] Work Trips BART	Work Trips NBA	Shopping Trips BART	Shopping Trips NBA	Savings (Increase) with BART Work Trips Actual	Work Trips Percent	Shopping Trips Actual	Shopping Trips Percent
Bay Fair	179	46.7	52.0	38.5	47.6	3.3	6.4	9.1	19
East Oakland	161	40.7	45.9	27.2	30.4	5.2	11	3.2	11
El Cerrito	120	42.1	48.2	31.6	35.8	6.1	13	4.2	12
Fremont	203	83.3	92.0	56.0	-[b]	6.7	7.3	-	-
Fruitvale	159	37.5	40.7	28.2	28.2	3.2	7.9	-	-
Mission District	387	26.9	32.0	32.0	35.1	5.1	16	3.1	8.8
Richmond	118	39.8	40.5	40.7	36.6	0.7	1.7	(4.1)	(11)
Rockridge	137	32.9	36.5	28.9	30.7	3.6	10	1.8	5.9
Walnut Creek	99	48.1	56.2	37.9	68.1	8.1	14	30.2	44
AVERAGE		44.2	49.3	35.7	39.1	5.1	10	3.4	8.7

(a) Computed as a one-to-many measure using zone to zone work trips and shopping trips for weighting purposes.

(b) No off-peak transit service assessment for the NBA.

Source: Metropolitan Transportation Commission; Peat, Marwick, Mitchell & Company, Inc.

TABLE 5. RESIDENCE OF DAYTIME BART RIDERS BY LINE SEGMENT

Station to Station Line Segment	Distribution of Reported Residences (Percent)	Estimated BART Riders[a]
CONCORD-ORINDA		
Concord	23.5	3,290
Lafayette	9.6	1,340
Moraga	5.6	780
Orinda	6.7	940
Pleasant Hill	7.3	1,020
San Ramon Valley	4.1	570
Walnut Creek	23.7	3,320
Other Areas	19.5	2,730
TOTAL	100.0	14,000
RICHMOND-EL CERRITO PLAZA		
El Cerrito	28.1	1,290
Richmond	27.9	1,280
San Pablo	5.6	260
Other Areas	38.4	1,770
TOTAL	100.0	4,600
FREMONT-SAN LEANDRO		
Castro Valley	4.6	710
Fremont	16.8	2,590
Hayward	26.4	4,070
Livermore-Amador Valley	3.9	600
Santa Clara County	8.0	1,230
San Leandro	16.7	2,570
Union City	8.0	1,230
Other Areas	15.6	2,400
TOTAL	100.0	15,400
DALY CITY-GLEN PARK		
Daly City	23.5	3,670
Pacifica	7.4	1,150
San Francisco	46.4	7,240
Other San Mateo County	22.7	3,540
TOTAL	100.0	15,600

a. Based on average daily 6:00 AM to 8:00 PM patronage, February 1977.

Source: 1976 BART Passenger Profile Survey

STATION AREA AUTO ACCESS

Using MTC's 1976 regional highway network, peak hour automobile travel times to 14 BART stations were calculated and mapped in three minute intervals up to 15 minutes, or 20 minutes for end-of-the-line stations. Stations selected for this analysis include:

Concord
Walnut Creek
Rockridge

Daly City
24th Street Mission
16th Street Mission

Richmond
El Cerrito Plaza

Fremont
Union City
South Hayward
Hayward
Bay Fair
Fruitvale

For each BART station travel times from 75 to 150 network nodes were plotted; then contour maps were produced using a computer mapping program (SYMAP). The published maps have been adjusted to reflect the local circulation system and urbanization patterns and to exclude inaccessible areas — hills, marshes, lakes, major parks, quarries, and the Bay.

Graphs illustrating the relationship between access times and distance from the BART station were drawn to correspond with the cross section lines indicated on the map borders. In each graph the changing slope of the line represents the relative drop in accessibility to BART at any given point; the flatter the slope the greater the station catchment area. Discontinuities are caused by the local streets and arterials which do not provide equal service everywhere.

To put the time intervals in perspective, histograms showing the distribution of AM driving times to BART reported in the 1976 BART Passenger Profile Survey are included next to each map; the cumulative distribution of auto access times is shown in Table 6. For most stations 75 to 90 percent of the patrons live no further than 10 minutes driving time to BART. End-of-the-line stations — Concord, Daly City, Fremont, and Richmond — are the exception because they serve larger catchment areas.

The principal findings of the station area accessibility analyses are summarized in the following sections.

TABLE 6. CUMULATIVE DISTRIBUTION OF AUTO ACCESS TIMES TO BART
(Home-Based Work Trips)

BART Station	Average Travel Time to BART				
	5 Minutes or Less	5.1-10 Minutes	10.1-15 Minutes	15.1-20 Minutes	Over 20 Minutes
Concord	33.3%	66.7%	84.7%	95.0%	100.0%
Walnut Creek	32.0	74.7	96.4	98.0	100.0
Rockridge	48.9	83.2	93.9	99.0	100.0
Richmond	44.9	63.7	75.6	87.5	100.0
El Cerrito Plaza	76.6	91.0	98.7	98.7	100.0
Fremont	39.1	62.5	77.0	84.2	100.0
Union City	40.0	82.8	95.3	97.9	100.0
South Hayward	59.6	90.6	97.9	97.9	100.0
Hayward	40.3	79.7	90.1	95.5	100.0
Bay Fair	47.5	80.8	86.4	93.0	100.0
Fruitvale	46.8	77.5	88.8	93.1	100.0
Daly City	22.8	69.4	85.8	98.4	100.0
24th Street Mission	56.0	100.0	-	-	-
16th Street Mission	45.2	88.7	96.8	100.0	-

a. Average access travel time by mode and the percentage distribution of access times for all modes are published in the Travel Data for BART Station Area Case Studies Working Note, TSTB Project Work Element VII-4; Peat, Marwick, Mitchell & Co., Inc., May 1977, p. 8.

Source: 1976 BART Passenger Profile Survey

Concord — Because of a good local arterial system, almost all of the city of Concord is no more than a six minute drive to BART. Residents of Pittsburg and Martinez must drive 12-15 minutes to ride BART to work, while those living in Antioch are 18+ minutes away. About two thirds of commuters driving or carpooling to the Concord station spend less than 10 minutes getting to BART.

Walnut Creek — Only those living on the outskirts of the city are more than six minutes away from BART during morning commute hours. In the San Ramon Valley the I-680 freeway provides excellent accessibility to BART; from Alamo it is only a 6-9 minute drive to the station, while Danville lies between the 9 and 12 minute contours. To the northeast the Pleasant Hill BART station is located within the 6-9 minute contour, indicating few central Contra Costa County residents need drive more than 7.5-9 minutes to BART. In fact, three quarters of the Walnut Creek patrons riding BART to work report driving time to BART of under 10 minutes.

Rockridge — The three minute contour includes all those living within a mile of BART, while the six minute contour encompasses an area of about 10 square miles, approximately bounded by Ashby and Shattuck to the north and west and Pleasant Valley and Moraga to the south. Close to half the morning riders driving to BART live within 5 minutes of the station.

Daly City — About half of the people living in Daly City are within six minutes driving time to BART during morning and evening commute hours; the remainder are 6-9 minutes away except for some of those in the Palisades Terrace area west of Westmoor Park who live within the 9-12 minute contours. Pacifica BART commuters take 9-15 minutes to drive to the Daly City station. With these longer travel times, it is not surprising that close to 30 percent of Daly City patrons using an automobile to get to BART report average travel times over 10 minutes and close to 50 percent, 5-10 minutes.

Mission District — Anyone living in the Inner Mission is within three minutes drive of a BART station, and with 9 Muni lines serving the Mission, taking a bus to BART — riding time alone — probably is not much more. In fact, about half of those driving to BART in the Mission report auto access times under 5 minutes: 56 percent for the 24th and Mission Street station and 45 percent for the 16th and Mission Street station.

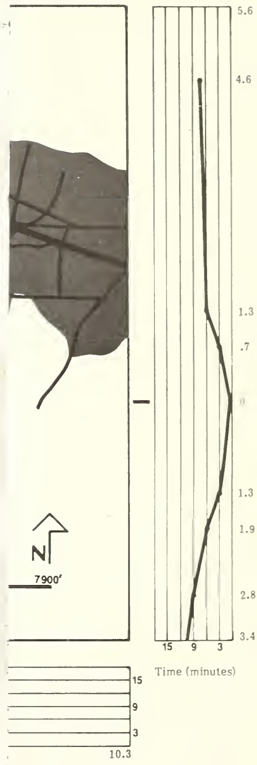
Richmond — Most Richmond residents could drive to BART within 9 minutes, while those living in El Sobrante, Pinole, and Hercules are 15-18 minutes away. For most riders coming from areas north of San Pablo, the I-80 freeway access to the El Cerrito Del Norte station is faster than arterial street access to the Richmond station. In comparison with other end-of-the-line stations, Richmond has by far the greatest proportion of commuters reporting auto access times of 5 minutes or less; 45 percent vs. 22 percent for Daly City, 33 percent for Concord, and 39 percent for Fremont.

El Cerrito Plaza -- The 0-3 minute contours include people living within one mile of the station, while the 3-6 minute contours extend north to Potrero Avenue, west to Arlington Boulevard, and south to Marin Avenue. Given accessible BART stations both north and south, the high proportion of those reporting morning driving times under 5 minutes, 77 percent, is to be expected.

Fruitvale -- The six minute travel time contour bounds an area of about 4 square miles around the BART station, extending from about 23rd Avenue to 52nd Avenue on a northwest-southeast axis. The nine minute contour encompasses neighborhoods to the northeast up to the I-580 MacArthur freeway. About three quarters of the BART commuters driving or carpooling to the Fruitvale station report travel times of 10 minutes or less, suggesting that at most a quarter of the Fruitvale riders live in the Oakland hills west of I-580.

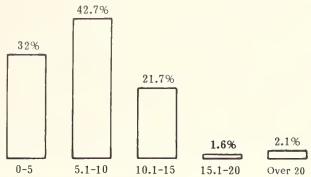
Bay Fair to Fremont -- Along the Fremont line south of San Leandro, most residents living west of Route 17, the Nimitz Freeway, are no more than six minutes away from a BART station. The map clearly illustrates how effectively major arterials such as Tennyson Road in Hayward or Alvarado and Niles in Union City can enlarge a station's catchment area within a given travel time. In the case of the South Hayward station this local accessibility is reflected in the high percentage of park and ride and carpooling patrons and those just dropped off -- a total of 60 percent -- who travel no more than 5 minutes to BART.

FOLDOUT



STATION AREA AUTO ACCESS
WALNUT CREEK

DISTRIBUTION OF A.M. ACCESS TIMES
(Home-Based Work Trips in Minutes)
Source: 1976 BART Passenger Profile Survey

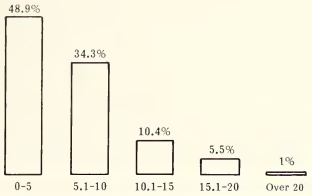


PEAK HOUR AUTO ACCESS TIME (Minutes)

- Undeveloped Space Excluded from Analysis
- 3 or less
- 3.01 - 6
- 6.01 - 9
- 9.01 - 12
- 12.01 - 15
- Over 15
- BART Right of Way
- BART Station
- Freeway
- Major Arterial

STATION AREA AUTO ACCESS
ROCKRIDGE

DISTRIBUTION OF A.M. ACCESS TIMES
(Home-Based Work Trips in Minutes)
Source: 1976 BART Passenger Profile Survey



PEAK HOUR AUTO ACCESS TIME (Minutes)

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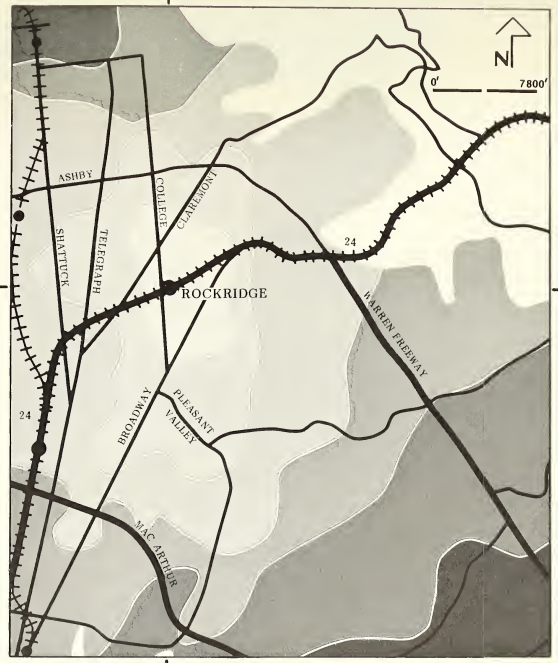
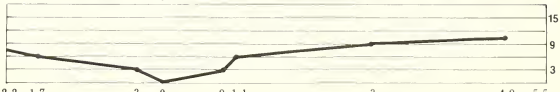
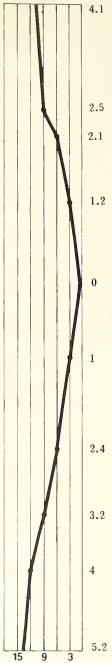
- 12.01 - 15
- Over 15
- BART Right of Way
- BART Station
- Freeway
- Major Arterial





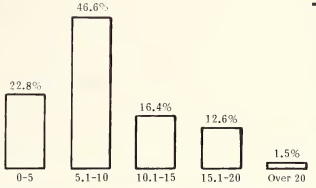
Distance (miles)



Time (minutes)

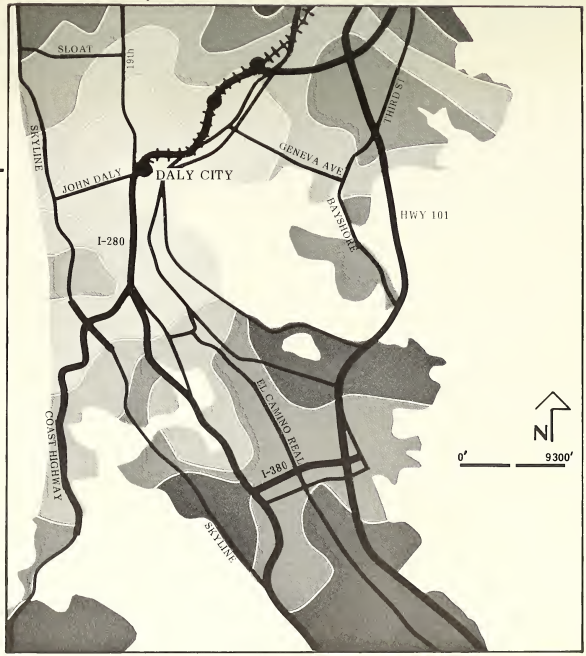
STATION AREA AUTO ACCESS
DALY CITY

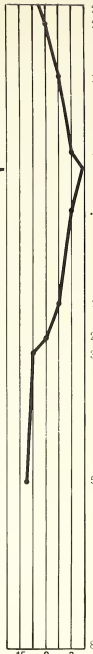
DISTRIBUTION OF A.M. ACCESS TIMES
(Home-Based Work Trips in Minutes)
Source: 1976 BART Passenger Profile Survey

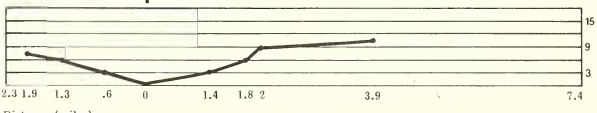


PEAK HOUR AUTO ACCESS TIME (Minutes)

- Undeveloped Space Excluded from Analysis
- 3 or less
- 3.01 - 6
- 6.01 - 9
- 9.01 - 12
- 12.01 - 15
- Over 15
- BART Right of Way
- BART Station
- Freeway
- Major Arterial



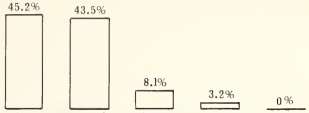




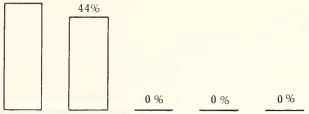
STATION AREA AUTO ACCESS
16th and 24th MISSION

DISTRIBUTION OF A.M. ACCESS TIMES
(Home-Based Work Trips in Minutes)
Source: 1976 BART Passenger Profile Survey

16th & MISSION

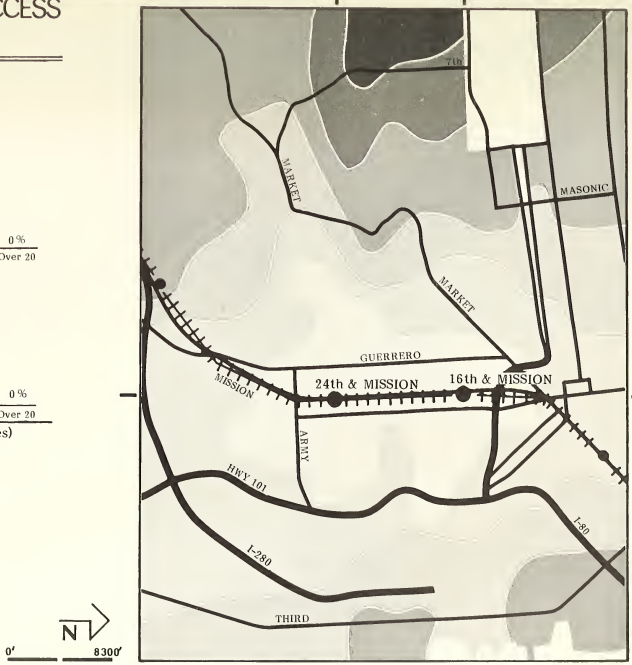


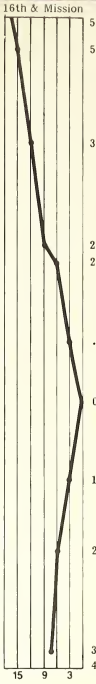
24th & MISSION

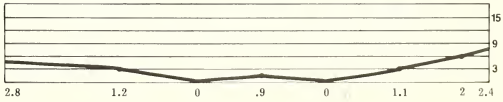


PEAK HOUR AUTO ACCESS TIME (Minutes)

- Undeveloped Space Excluded from Analysis
- 3 or less
- 3.01 - 6
- 6.01 - 9
- 9.01 - 12
- 12.01 - 15
- Over 15
- BART Right of Way
- BART Station
- Freeway
- Major Arterial

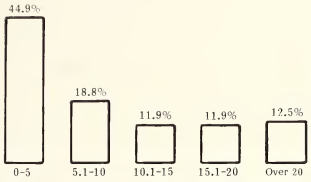






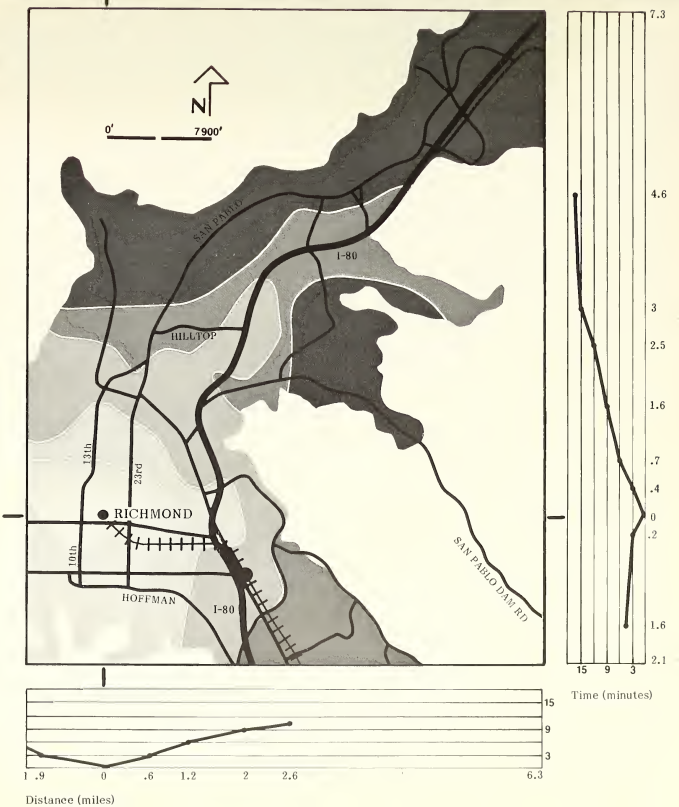
STATION AREA AUTO ACCESS
RICHMOND

DISTRIBUTION OF A.M. ACCESS TIMES
(Home-Based Work Trips in Minutes)
Source: 1976 BART Passenger Profile Survey



PEAK HOUR AUTO ACCESS TIME (Minutes)

- Undeveloped Space Excluded from Analysis
- 3 or less
- 3.01 - 6
- 6.01 - 9
- 9.01 - 12
- 12.01 - 15
- Over 15
- BART Right of Way
- BART Station
- Freeway
- Major Arterial



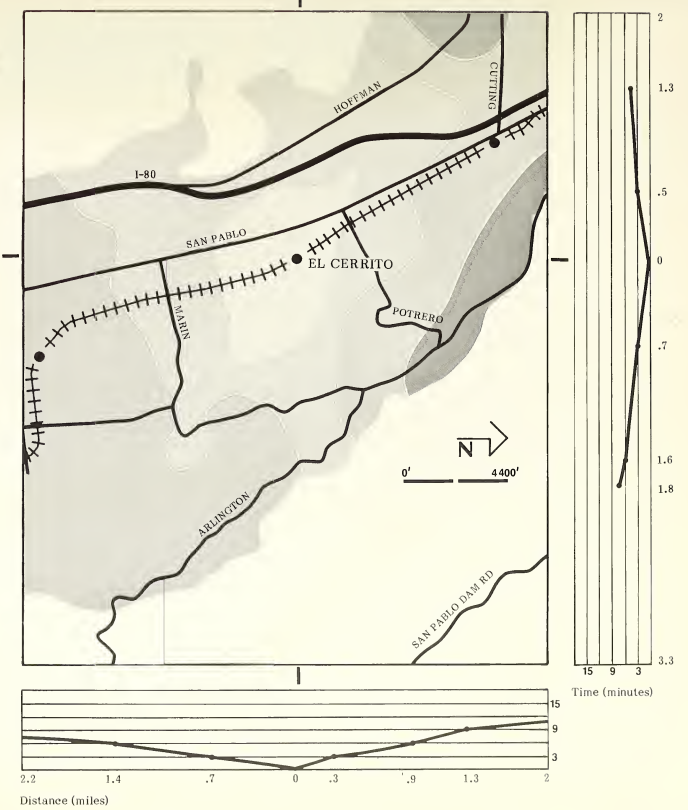
STATION AREA AUTO ACCESS
EL CERRITO

DISTRIBUTION OF A.M. ACCESS TIMES
(Home-Based Work Trips in Minutes)

Source: 1976 BART Passenger Profile Survey

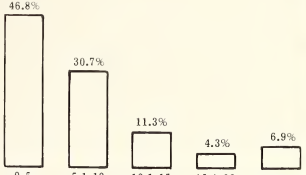
PEAK HOUR AUTO ACCESS TIME (Minutes)

- Undeveloped Space Excluded from Analysis
- 3 or less
- 3.01 - 6
- 6.01 - 9
- 9.01 - 12
- 12.01 - 15
- Over 15
- BART Right of Way
- BART Station
- Freeway
- Major Arterial



STATION AREA AUTO ACCESS
FRUITVALE

DISTRIBUTION OF A.M. ACCESS TIMES
(Home-Based Work Trips in Minutes)
Source: 1976 BART Passenger Profile Survey



PEAK HOUR AUTO ACCESS TIME (Minutes)

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- 3 or less
- 3.01 - 6
- 6.01 - 9
- 9.01 - 12
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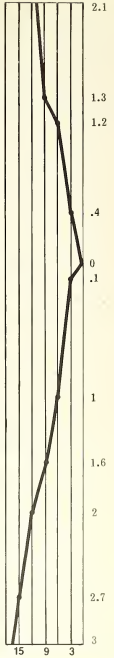
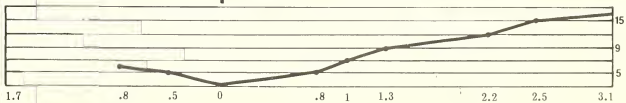
- Freeway
- Major Arterial



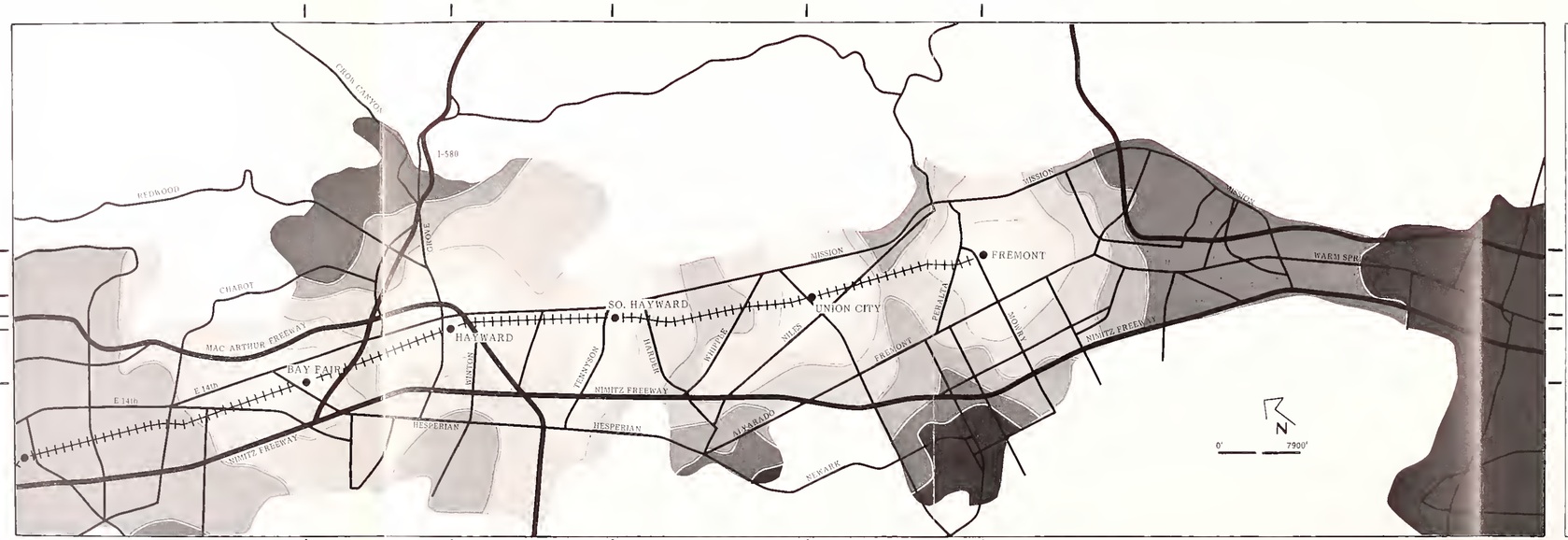


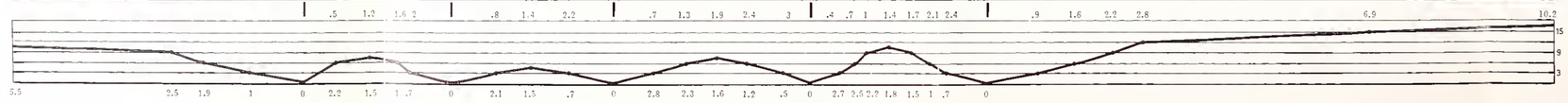
Distance (miles)

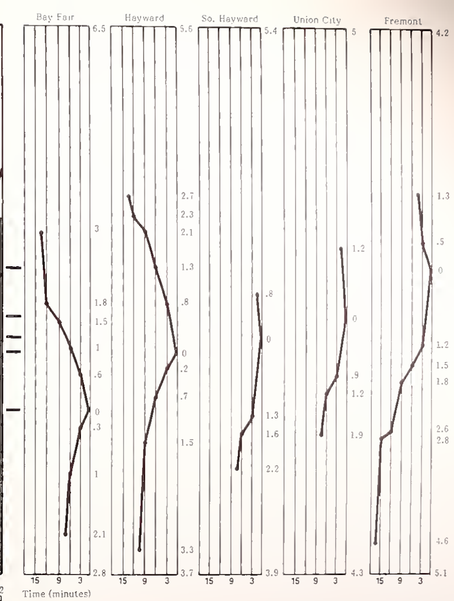
STATION AREA AUTO ACCESS
BAY FAIR
HAYWARD
SOUTH HAYWARD
UNION CITY
FREMONT

PEAK HOUR AUTO ACCESS TIME (Minutes)

- Undeveloped Space Excluded from Analysis
- 3 or less
- 3.01-6
- 6.01 - 9
- 9.01 - 12
- 12.01 - 15
- Over 15
- BART Right of Way
- BART Station
- Freeway
- Major Arterial

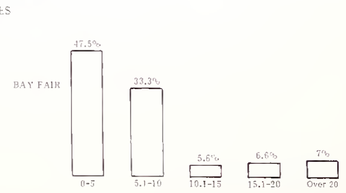


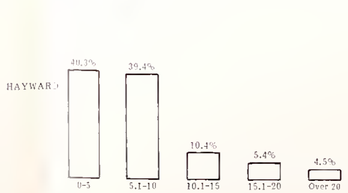


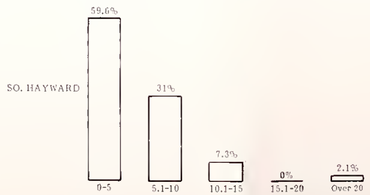


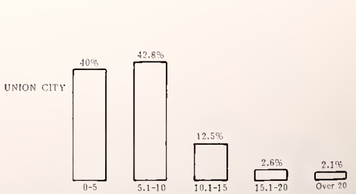
DISTRIBUTION OF A.M. ACCESS TIMES
(Home-Based Work Trips in Minutes)

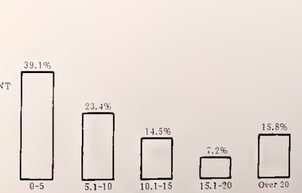
Source: 1976 BART Passenger Profile Survey











4. CONCLUSIONS

The accessibility mapping effort was designed to provide an information base for use in analyzing BART's effects on land use and urban development. The principal conclusions of this work element are:

- BART offers a measurable improvement in area-wide accessibility to about 34 percent of the four-county service area populations with a median improvement in average peak hour transit travel time of 14 minutes over the NBA.

- BART's effect on mobility, taking actual trips into account, is relatively small. For example, the average work trip by transit to major employment centers is shortened by 8.7 minutes (20 percent), and the average shopping trip by transit is shortened by 2.8 minutes (8 percent).

- Geographically the greatest accessibility and mobility gains are found along the Fremont BART line, followed in descending order by the Concord line, the Daly City line, and the Richmond line.

- BART ridership rates, patrons per thousand population, are not uniformly correlated with accessibility and mobility gains because destinations of residents and attributes of competing modes still may make BART less attractive.

- In all but end-of-the-line communities directly served by BART, 75 to 90 percent of the patrons live within 10 minutes driving time of the station.

The results of this quantitative analysis of BART's effects on accessibility and mobility will be correlated with the surveys of workers (Work Element 4), households (Work Element 3), and shoppers (Work Element 9) to determine how well people's perceptions of BART and changes of behavior or decisions attributable to BART match the gains in transportation service BART offers. Areas where BART has had the greatest impact on location decisions, shopping patterns, or possibly property values and rents may or may not be the areas with the greatest accessibility and mobility gains.

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